M.TECH – Energy Science and Technology (EST) SYLLABUS

Course Credit Distribution:

Category	Core Subject	Elective Subject	Comprehensive Viva	Project	Total credit
Credits	27+3 = 30	9	1	20	60

Semester wise Credit Distribution:

Category	Course types	Credits	Total
Semester I	Core course – 5 Nos (4 theory courses + 1 laboratory) Elective Course – 1 Nos Compulsory Course – 1 Nos	5 × 3 = 15 1 × 3 = 3 1 × 0 = 0	18
Semester II	Core course – 4 Nos (3 theory courses + 1 laboratory) Elective Course – 2 Nos	4 × 3 = 12 2 × 3 = 6	18
Semester III	Summer Research Internship Comprehensive Viva Core course – 1 Nos M. Tech Thesis/Project	0 1 3 8	12
Semester IV	M. Tech Thesis/Project	12	12

Semester wise Subject code and Course Name:

Core Courses			Elective courses	
Category	**Subject code**	**Course Name**	**Subject code**	**Course Name**
Semester I	EST 101 EST 102 EST 103 EST 104 EST 105 EST 106	Energy Sources Fuel and Combustion Energy Conversion and Storage System Foundation for Energy Technology Energy Systems Lab Technical English Language Training (Writing/ Presentation) (**Compulsory course**)	ESTE1 107 ESTE1 108 ESTE1 109 ESTE1 110	Introduction to Nanotechnology Energy and Climate Waste Management And Energy Generation Technologies Advanced Applied Mathematics
Semester II	EST 201 EST 202 EST 203 EST 204	Introduction to the Energy materials and Fundamentals of Energy Devices Energy Audit And Management Solar Energy Engineering Energy conversion and storage Lab	ESTE2 205 ESTE2 206 ESTE2 207 ESTE2 208 ESTE2 209 ESTE2 210	Bio Energy Engineering Hydrogen Energy Power Sources For Electric Vehicles Wind Energy Conversion Systems Nuclear Reactor Theory Overview of Material Characterization Techniques
Semester III	EST 301 EST 302 EST 303 EST 304	**Summer Research Internship** (**Compulsory course**) Comprehensive Viva Research Methodology & Technical Writing M. Tech Thesis/Project		
Semester IV	EST 401	Final M. Tech Thesis/Project		

M.TECH – Energy Science and Technology (EST) SYLLABUS FOR Ist SEMESTER

EST 101 (AUG)
Energy Sources
L-T-P: 3-1-0

Energy and Development, Units and Measurements, Conventional and Non-Conventional sources of Energy, Fossil and Mineral Energy Resources, Details of Coal, Peat, Oil, Natural Gas and Nuclear Resources, Recovery of Fossil Fuels, Classification and Characterization of Fossil fuels, Basic of Solar, Wind, Bio, Hydro, Tidal, Ocean Thermal and other Renewable Energy Sources, Electricity generation, distribution and use, Basic of Solar Thermal Conversion, Technology of Selective Coating, Fundamentals of Flat Plate Collector and Evacuated Collector, Basic of Wind Energy conversion, Wind machine, Wind electric generator, Wind pump Impact of Energy on Environment, Flow of Energy in Ecological System, Environmental Degradation due to energy, Control of Pollution from Energy.

Text books & Reference books:

- Koteswar Rao, Energy Resources: Conventional and Non-Conventional, 2ND EDITION, BSP.
- S. P. Sukhatme, Solar Energy - Principles of thermal collection and storage, second edition, Tata McGraw-Hill, New Delhi, 1996
- B H Khan, Non Conventional Energy Resources, 3rd Edn
- Shobh Nath Singh, Non Conventional Energy Resources
- Ghosh Roy, RENEWABLE ENERGY
- David M. Buchla, Thomas E. Kissell, Thomas L. Floyd, Renewable Energy Systems
- S.C. Bhatia and R.K. Gupta, TEXTBOOK OF RENEWABLE ENERGY
- Anjaneyulu Yerramilli, Energy Resources, Utilization and Technologies, BSP
- Steeby Donald, Alternative Energy: Sources and Systems, Cengage India.
- Vladimir Strezov, Hossain Md. Anawar, Renewable Energy Systems From Biomass: Efficiency, Innovation and Sustainability, 1st Edition.
- Imene Yahyaoui, Advances In Renewable Energies And Power Technologies: Biomass, Fuel Cells, Geothermal Energies, and Smart Grids, Volume 2, 1st Edition
- D. Y. Goswami, F. Kreith and J. F. Kreider, Principles of Solar Engineering, Taylor and Francis, Philadelphia, 2000
- Boyle, Renewable Energy: Power For A Sustainable Future, 3rd Edn, Oxford University Press.
- Stephen Peake, Renewable Energy, 4th Edition, Oxford University Press.
- D. D. Hall and R. P. Grover, Biomass Regenerable Energy, John Wiley, New York, 1987.
- J. Twidell and T. Weir, Renewable Energy Resources, E & F N Spon Ltd, London, 1986.

EST 102 (AUG)
Fuel and Combustion
L-T-P: 3-1-0

Basics of fuels: Modern concepts of fuel, Solid, liquid and gaseous fuels, composition, basic understanding of various properties of solid fuels - heating value, ultimate analysis, proximate analysis, ash deformation points;

liquid fuels - heating value, density, specific gravity, viscosity, flash point, ignition point (self, forced), pour point, ash composition and gaseous fuels.

Coal as a source of energy: Coal reserves – World and India, Coal liquefaction process, various types of coal and their properties, Origin of coal, composition of coal, analysis and properties of coal, Action of heat on coal, caking and coking properties of coal; Processing of coal: Coal preparations, briquetting, carbonization, gasification and liquefaction of coal, Coal derived chemicals.

Petroleum as a source of energy and chemicals: Origin, composition, classification of petroleum, grading of petroleum; Processing of petroleum: Distillation of crude petroleum, petroleum products, purification of petroleum products – thermal processes, catalytic processes, specifications and characteristics of petroleum products.

Natural gas and its derivatives: Classification of gaseous fuels – natural gas and synthetic gases, Natural gas reserves - World and India, properties of natural gas – heating value, composition, density.

Principles of combustion: Chemistry and Stoichiometric calculation, thermodynamic analysis and concept of adiabatic flame temperature; Combustion appliances for solid, liquid and gaseous fuels: working, design principles and performance analysis.

Emissions from fuel combustion systems: Pollutants and their generation, allowed emissions, strategies for emission reduction, Euro and BIS norms for emission, recent protocols

Text books & Reference books:

- Sarkar S. (2010); Fuels and Combustion, Third Edition, CRC Press
- Dr. H.S. Mukunda, Understanding Clean Energy and Fuels from Biomass, Wiley India.
- S.P. Sharma & Chander Mohan, "Fuels & Combustion", Tata McGraw Hill Publishing Co.Ltd.,1984
- Jaccard M. (2006); Sustainable Fossil Fuels, Cambridge University Press
- Turns S. R. (2011); An Introduction to Combustion: Concepts and Applications, Third Edition, McGraw Hill
- Joseph Hirschi, Advances in Productive, Safe, and Responsible Coal Mining, 1st Edition
- Michael Blinderman Alexander Klimenko, Underground Coal Gasification and Combustion, 1st Edition
- Mukunda H. S. (2009); Understanding Combustion, Second Edition, Universities Press
- Glassman I. and Yetter R. (2008); Combustion, Fourth Edition, Academic Press
- Sharma B. K. (1998); Fuels and Petroleum Processing, First Edition, Goel publishing Gupta O. P.

EST 103 (AUG)
Energy Conversion and Storage System
L-T-P: 3-0-0

Basics of Photovoltaic Conversion technology and PV systems, PV system design methodologies, Basics of Bio-energy conversion, biomethanation technology, Thermochemical Conversion through Pyrolysis, Gasification and Esterification, Bio Oil, Application of Ocean Thermal Gradient and Geothermal gradient for power generation, Basics of hydropower, Tidal and Wave power, Basics of Hydrogen fuel, Basic of Electrochemistry: Electrochemical cells, Nernst equation and applications of Debye-Huckel-theory, Electrolytic conductivity and the Debye-Hückel-Onsangar treatment, electrified interfaces, overpotential, corrosion. Basic of Electrochemical energy conversion and storage, Fundamentals of Fuel Cells, Basics of Fusion power, Energy Storage Technologies, Mechanical storage, Chemical storage, Electrical storage.

Text books & Reference books:

- Angèle Reinders, Pierre Verlinden, Wilfried van Sark, Alexandre Freundlich, Photovoltaic Solar Energy: From Fundamentals to Applications, JOHN WILEY.
- Alexander P. Kirk, Solar Photovoltaic Cells : Photons To Electricity, ELSEVIER
- Francesco Dalena, Angelo Basile, Claudio Rossi, Bioenergy Systems For The Future: Prospects For Biofuels And Biohydrogen, 1st Edition, ELSEVIER
- Jean-Marie Tarascon, Patrice Simon , ELECTROCHEMICAL ENERGY STORAGE,

- Electrochemistry by Carl H. Hamann, Andrew Hamnett and Wolf Vielstich, Wiley VCH, 1998.
- Modern Electrochemistry 1. Volume 1 and 2, by J. O'M. Bockris and A. K. N. Reddy, Kluwer Academic, 2000.
- Electrochemical Methods, by A. J. Bard and L. R. Faulkner, John Willey, 1980
- John Love and John A. Bryant, Biofuels and Bioenergy, John Wiley
- Anju Dahiya, Bioenergy: Biomass to Biofuels, Elsevier

EST 104 (AUG)
Foundation for Energy Technology
L-T-P: 3-1-0

Thermodynamics: first law and its application, second law and its application, Irreversibility and energy, basic power generation cycles.
Fluid Mechanics: Fundamentals of fluid mechanics, concept of viscosity and its application, Flow equations: mass and momentum conservation, flow through pipe, a brief about fluid machineries.
Heat Transfer: Fundamentals of heat transfer & Principles of heat and mass transfer. Modes of heat transfer: conduction, radiation, and convection.
Electrical Machines: Transformer, Induction motor and generators, Synchronous generators, Introduction to modern speed control techniques, DC machines. Power systems: Introduction to power transmission and distribution. Network analysis: simple network analysis, power factor improvement.

Text books and Refrences books:

- Nag P. K. (2014); *Basic and Applied Thermodynamics*, McGraw Hill.
- Veera Gnaneswar Gude, RENEWABLE ENERGY POWERED DESALINATION HANDBOOK : APPLICATION AND THERMODYNAMICS, 1ST EDITION
- Sanjeev Chandra, ENERGY, ENTROPY AND ENGINES: AN INTRODUCTION TO THERMODYNAMICS, JOHN WILEY
- M. W. Zemansky, Heat and Thermodynamics 4th Edn. McGraw Hill, 1968.
- ORLANDE,H.R.B. & FUDYM,O. ET.AL, THERMAL MEASUREMENTS AND INVERSE TECHNIQUES (SERIES: HEAT TRANSFER), T&F INDIA
- Theraja B. L. and Theraja A. K. (1998); *A Text Book in Electrical Technology*, S. Chand and Co.
- A. L. Prasuhn, Fundamentals of Fluid Mechanics, Prentice Hall, 1980
- S. P. Sukhatme, A Text book on Heat Transfer, Orient Longman, 1979.
- P. C. Sen, Modern Power Electronics, Wheeler, New Delhi, 1998.
- V.V.L. Rao, UTILISATION OF ELECTRICAL ENERGY IN SI UNITS, UNIVERSITIES PRESS
- N. Balbanian, T. A. Bickart, Electrical network theory, John Wiley, New York, 1969
- B. L. Theraja, A. K. Theraja, Text-book of electrical technology: in S.I. units: v.2 AC and DC machines, Nirja Construction & development, New Delhi, 1988.

EST 105 (AUG)
Energy System Laboratory
L-T-P: 0-0-6

In this course, Students will learn how to turn solar cells into solar modules and how solar modules are used to make photovoltaic systems. The course will cover the design of photovoltaic systems, ranging from utility scale solar farms to residential scale systems stand alone and grid connected systems. Students will learn about the function and operation of various PV system components, including inverters, batteries, DC-DC converters and

the grid. Students will obtain an in-depth understanding of the main design decisions for planning a PV installation with excellent performance and reliability.
Student will also learn the basic of the electrochemical energy conversion and storage devices.

Lecture Notes &Reference books:

- Solar Photovoltaics: Fundamentals, Technologies And Applications, 3rd Edition, by CHETAN SINGH SOLANKI (IIT Bombay).
- The Physics of Solar Cells by JENNY NELSON (Imperial College, UK)
- Solar Energy The physics and engineering of photovoltaic conversion, technologies and systems by ARNO SMETS.
- Solar Cell Device Physics by STEPHEN FONASH.

EST 106 (AUG) 0:0 (Compulsory)
Technical English Language Training (Writing/ Presentation)

This course is designed to help students learn to write their manuscripts, reports, and dissertations in a competent manner. **The do's and don'ts of the English language will be dealt with primarily as a part of the course**. Assignments will include writing on topics to a student's research interest, so that the course may benefit each student directly.

ESTE1 107 (AUG) *(Elective)*
Introduction to Nanotechnology
L-T-P: 3-1-0

This course introduces students to the field of Nano Science and Technology. This includes nanofabrication technology (how one achieves the nanometre length scale, from "bottom up" to "top down" technologies), the interdisciplinary nature of nanotechnology and nanoscience (including areas of chemistry, material science, physics, and molecular biology), examples of nanoscience phenomena (the crossover from bulk to quantum mechanical properties), and applications (from integrated circuits, quantum computing, MEMS, Nano-magnetics and bioengineering). Introduction to advanced optics such as LASERS, plasmonics, biophotonics, nanophotonics, non-linear optics etc. Students will be asked to read and present a variety of current journal papers to the class and lead a discussion on the various works.

Text books & Reference books:

- S. M Lindsay, Introduction to Nanoscience, Oxford (2010)
- Charles P. Poole Jr. & Frank J. Owens, Introduction to Nanotechnology, Wiley (2003)
- M.S. Ramachandra Rao, Nanoscience and Nanotechnology: Fundamentals of Frontiers, Wiley
- M.A. Shah, Nanotechnology: The Science of Small, Wiley (2013)
- Cao G., Nanostructures and Nanomaterials, Synthesis Properties and Applications, Imperial College Press, 2004
- Bharat Bhushan, Handbook of nanotechnology

ESTE1 108 (AUG) *(Elective)*
Energy and Climate
L-T-P: 3-1-0

Energy and us: Energy terms; current energy scenario (World, US, India); Fossil energy Vs renewable sources; Green energy and green chemistry, Electricity; Future projections; Externalities of energy use.

Carbon Cycle: Natural systems autotrophs, heterotrophs, energy flows, pre-industrial humanity; Photosynthesis-efficiency of natural ecosystems, forests and various crops; Respiration, combustion and other oxidation processes; Biomethanation

Climate Science Research: Climate history; Greenhouse gas effect; Anthropogenic climate change; Role of different gases; Global problem; Integrated assessment models; Impacts and adaptation; Uncertainties; Precautionary principle

Carbon Sequestration: Biological pathways; Physico-chemical methods; CO_2 capture from large point sources; Pre-, post- and oxy-combustion technology; Transport, storage and monitoring; Feasibility, economics and public perceptions; Case studies

Climate Policy: Kyoto protocol; UNFCCC; IPCC; Geopolitics of GHG control; Carbon market - CDM and other emission trading mechanisms; Non-CO_2 GHGs; Relevance for India

Text books & Reference books:

- Energies: V Smil, MIT Press, Cambridge, 1999.
- Global Warming: J Houghton, Cambridge University Press, New York, 1997
- Volker V. Quaschning, Renewable Energy and Climate Change, 2nd Edition, John Wiley
- Julie A. Kerr, Introduction To Energy and Climate : Developing A Sustainable Environment, T&F/Crc Press.
- Michael B. McElroy, Energy and Climate: Vision for The Future, Oxford University Press
- Valentin Crasta, Global Energy Economics and Climate Protection Report 2009, Springer
- Various reports published by IPCC: http://www.ipcc.ch/, 1990 onwards
- IPCC Special Report on Carbon Dioxide Capture and Storage: B Metz et al (Eds), Cambridge University Press, NY, 2005.
- Efstathios E. Michaelides, Energy The Environment, And Sustainability, 1st Edition
- Cdm Country Guide For India: Institute for Global Environmental Strategies (Ed), Ministry of the Environment, Japan, 2005.
- Global Environmental Issues:F Harris (Ed),John Wiley,Chichester, 2004.
- Carbon Capture and Sequestration: Integrating Technology, Monitoring, and Regulation. edited by E J Wilson and D Gerard, Blackwell Publishing, Ames, Iowa, USA, 2007
- Energy and the environment: J A Fay and D S Golomb, Oxford University Press, New York, 2002.
- Introduction to Engineering and the Environment: E S Rubin, McGraw Hill, New York, 2001

ESTE1 109 (AUG) *(Elective)*
Waste Management and Energy Generation Technologies
L-T-P: 3-1-0

Sources, Types, Compositions, Properties Physical, Chemical and Biological - Collection - Transfer Stations – Waste minimization and recycling of Municipal Waste.

Size Reduction - Aerobic Composting - Incineration for Medical /Pharmaceutical Waste -Environmental Impacts -Environmental Effects due to Incineration.

Land Fill Method- Types, Methods & Siting Consideration - Composition, Characteristics,generation, Control of Landfill Leachate & Gases – Environmental monitoring System for Land Fill Gases.

Sources and Nature of Hazardous Waste - Impact on Environment - Hazardous Waste -Disposal of Hazardous Waste, Underground Storage Tanks Construction, Installation & Closure.

Biochemical Conversion - Industrial , Agro Residues - Anaerobic Digestion - Biogas Production - Types of Biogas Plant-Thermochemical Conversion -Gasification - Types - Briquetting - Industrial Applications of Gasifiers - Environment Benefits.

Text books & Reference books:

- Shah, Kanti L., Basics of Solid & Hazardous Waste Management Technology, Printice Hall, 2000
- Parker, Colin, & Roberts, Energy from Waste - An Evaluation of Conversion Technologies, Elsevier Applied Science, London, 1985
- Thomas Trabold Callie W. Babbitt, SUSTAINABLE FOOD WASTE-TO-ENERGY SYSTEMS, 1ST EDITION, ELSEVIER

ESTE1 110 (AUG) *(Elective)*
Advanced Applied Mathematics
L-T-P: 3-1-0

Outlines of Statistics, simple ways of summarizing data, the concept of probability, Sampling Distribution: Discrete distribution, continuous distribution (mathematical expectations- moment generating functions and characteristic functions. Binomial, Poisson, Geometric, Uniform, Exponential, Normal distribution Functions (MGF, mean, variance, and simple problems), Theory of estimation: point estimation, interval estimation, Testing of Hypothesis: Significance Test, regression and correlations, test based on chi-square distribution & t & F distribution. Design and analysis of experiments- comparative experiments, Design and analysis of experiments-factorial experiments.
Numerical Methods for PDE: Elliptic, Parabolic and Hyperbolic Partial differential equations, Neumann method for irregular boundary
The course will use, uses examples from courses EST –103, 105 to introduce mathematical concepts and materials-related problem-solving skills. Topics include linear algebra and orthonormal basis, eigenvalues and eigenvectors, quadratic forms, tensor operations, symmetry operations, calculus of several variables, introduction to complex analysis, ordinary and partial differential equations, theory of distributions, Fourier analysis and random walks. Basic programming in PYTHON and/or MATLAB using simple examples.

Text books & Reference books:

- Larry Wasserman (2004), All of Statistics: A Concise Course in Statistics, Springer Publication House, October, 2004
- Ferguson, T. (1996). "A Course in Large Sample Theory" Chapman & Hall/CRC
- Introduction to Numerical Analysis: Second Edition (Dover Books on Mathematics): F.B. Hildebrand
- Lehmann, E. (2004). "Elements of Large-Sample Theory" Springer.

M.TECH – Energy Science and Technology (EST) SYLLABUS FOR IInd SEMESTER

EST 201 (JAN)
Introduction to the Energy materials and Fundamentals of Energy Devices
L-T-P: 3-1-0

Introduction to physics of semiconductor devices and basics of solar cells; High efficiency solar cells, PERL Si solar cell, III-V high efficiency solar cells, GaAs solar cells, tandem and multi-junction solar cells, solar PV concentrator cells and systems, III-V, II-VI thin-film solar cells (GaAs, Cu(In,Ga)Se_2, CdTe) Nano-, micro- and poly-crystalline Si for solar cells, mono-micro silicon composite structure, crystalline silicon deposition techniques, material and solar cell characterization, advanced solar cell concepts and technologies (Porous Si layer transfer, Metal induced crystallization, etc.). Amorphous silicon thin-film (and/or flexible) technologies, multi-junction (tandem) solar cells, stacked solar cells. Conjugated polymers, organic/plastic/flexible solar cells, polymer composites for solar cells, device fabrication and characterization.
Basic of electrochemical energy devices; mechanism and materials for different types of batteries, supercapacitor and hybrid; fuel cells (Polymer membranes for fuel cells, PEM fuel cell, Acid/alkaline fuel cells.), electrochemical and photoelectrochemical water splitting. Details of Pb-acid Nickel-metal hydride (Ni-MH), Ni-Cd-alkaline battery, Ni-iron, Li/Na-ion, Mg-ion, Li/Na-S batteries, Metal-air battery, battery maintenance and safety precautions. Application of phase-change materials for energy conservation.

Text books & Reference books:

- Solar cells: Operating principles, technology and system applications, by Martin A. Green, Prentice-Hall Inc, Englewood Cliffs, NJ, USA, 1981.
- Adrian Kitai, Principles of Solar Cells, Leds And Related Devices: The Role Of The Pn Junction, 2nd Edition. John Wiley
- JOHN WILEY, Vasilis M. Fthenakis, Paul A. Lynn, Electricity From Sunlight: Photovoltaic-Systems Integration And Sustainability, 2nd Edition
- Juan Bisquert, Physics Of Solar Cells : Perovskites, Organics, And Photovoltaic Fundamentals, T&F/Crc Press
- Physics of Semiconductor Devices, 3rd Edition by S M. Sze, Kwok K. Ng
- Guangyu Wang, TECHNOLOGY, MANUFACTURING AND GRID CONNECTION OF PHOTOVOLTAIC SOLAR CELLS, JOHN WILEY
- Soteris Kalogirou, MCEVOYS HANDBOOK OF PHOTOVOLTAICS : FUNDAMENTALS AND APPLICATIONS, 3RD EDN, ELSEVIER
- Seminconductors for solar cells, H. J. Moller, Artech House Inc, MA, USA, 1993. Solid State electronic devices, Ben G. Streetman, , Prentice-Hall of India Pvt. Ltd., New delhi 1995.
- Carbon nanotubes and related structures: New material for twenty-first century, P. J. F. Harris, Cambridge University Press, 1999.
- Thin-film crystalline silicon solar cells: Physics and technology, R. Brendel, Wiley-VCH, Weinheim, 2003.
- Clean electricity from photovoltaics, M. D. Archer, R. Hill, Imperial college press, 2001.
- Organic photovoltaics: Concepts and realization, C. Barbec, V. Dyakonov, J. Parisi, N. S. Saricifttci, Springer-Verlag 2003.
- Fuel cell and their applications, K. Kordesch, G. Simader, VCH, Weinheim, Germany, 1996.
- Paul Breeze, Fuel Cells, 1st Edition, Elsevier
- Nigel P.Brandon, Enrique Ruiz-Trejo and Paul Boldrin, Solid Oxide Fuel Cell Lifetime And Reliability : Critical Challenges In Fuel Cells, 1st Edition, Elsevier
- Allen J. Bard, Larry R. Faulkner, Electrochemical Methods, John Wiley & Sons, Inc
- Battery technology handbook, edited by H.A. Kiehne, Marcel Dekker, New York, 1989
- B. E. Conway Electrochemical Supercapacitors; Scientific Fundamentals and Technological Applications

- Pei Kang Shen, Chao-Yang Wang, San Ping Jiang, Xueliang Sun, Jiujun Zhang, Electrochemical Energy: Advanced Materials And Technologies
- Glaize Christian Et.Al, Lithium Batteries And Other Electrochemical Storage Systems.
- John Warner, The Handbook of Lithium-Ion Battery Pack Design.
- Christian Glaize Sylvie Geniès, Lithium Batteries and Other Electrochemical Storage Systems.
- Pei Kang Shen, Chao-Yang Wang, San Ping Jiang, Xueliang Sun, Jiujun Zhang, Electrochemical Energy: Advanced Materials and Technologies

EST 202 (JAN)
Energy Audit and Management
L-T-P: 3-1-0

Energy Scenario - Role of Energy Managers in Industries – Energy monitoring, auditing & targeting – Economics of various Energy Conservation schemes. Total Energy Systems Energy Audit -various Energy Conservation Measures in Steam -Losses in Boiler. Energy Conservation in Steam Systems -Case studies. Energy conservation in Centrifugal pumps, Fans &Blowers, Air compressor – energy consumption & energy saving potentials – Design consideration. Refrigeration & Air conditioning - Heat load estimation -Energy conservation in cooling towers & spray ponds – Case studies Electrical Energy -Energy Efficiency in Lighting – Case studies. Organizational background desired for energy management motivation, detailed process of M&T-Thermostats, Boiler controls-proportional, differential and integral control, optimizers; compensators.

Text books & Reference books:

- Eastop T.D & Croft D.R, Energy Efficiency for Engineers and Technologists, Logman Scientific & Technical, ISBN-0-582-03184, 1990.
- Barney L. Capehart, Wayne C. Turner, William J. Kennedy, Guide To Energy Management, 8th Edn, T&F/Routledge
- Amlan Chakrabarti, Energy Engineering And Management, 2nd Edition
- Sonal Desai, Handbook Of Energy Audit, Mc Graw Hill India
- Reay D.A, Industrial Energy Conservation, 1stedition, Pergamon Press, 1977.
- Larry C Whitetal, Industrial Energy Management & Utilization.
- Power System Engineering 2nd Ed. D P Kothari, I J Nagrath, Tata McGraw-Hill Co 2008.

EST 203 (JAN)
Solar Energy Engineering
L-T-P: 3-1-0

Source of radiation – solar constant– solar charts – Measurement of diffuse, global and direct solar radiation: pyrheliometer, pyranometer, pyregeometer, net pyradiometer-sunshine recorder.
Solar Non-Concentrating Collectors- Design considerations – Classification- air, liquid heating collectors – Derivation of efficiency and testing of flat plate collectors –Analysis of concentric tube collector - Solar green house.
Design – Classification– Concentrator mounting –Focusing solar concentrators- Heliostats. Solar powered absorption A/C system, water pump, chimney, drier, dehumidifier, still, cooker.
Photo-voltaic cell – characteristics-cell arrays-power electric circuits for output of solar panels-choppers-inverters-batteries-charge regulators, Construction concepts.

Energy Storage -Sensible, latent heat and thermo-chemical storage-pebble bed etc. materials for phase change-Glauber's salt-organic compounds. Solar ponds.

Text books & Reference books:

- D. Yogi Goswami, Frank Kreith, Jan. F. Kreider, "Principles of Solar Engineering", 2nd Edition, Taylor & Francis, 2000, Indian reprint, 2003
- Sukhatme, Solar Energy, 4th Edn, Mc Graw Hill India
- Brownson, Solar Energy Conversion Systems, Elsevier
- Enteria,N., Akbarzadeh,A., Solar Energy Sciences And Engineering Applications, T&F
- Edward E. Anderson, "Fundamentals for solar energy conversion", Addison Wesley Publ. Co., 1983.
- Duffie J. A and Beckman, W .A., "Solar Engineering of Thermal Process", John Wiley, 1991.
- G. N. Tiwari and M. K. Ghosal, "Fundamentals of Renewable energy Sources", Narosa Publishing House, New Delhi, 2007
- Energy Studies, Second Edition, by W. Shepherd and D. W. Shepherd, Imperial College Press, London, 2004

EST 204 (JAN)
Energy Conversion and Storage Lab
L-T-P: 0-0-6

Hands on laboratory experience + Viva + presentation

ESTE2 205 (JAN) *(Elective)*
Bio Energy Engineering
L-T-P: 3-1-0

Sources and Classification. Chemical composition, properties of biomass. Energy plantations .Size reduction, Briquetting, Drying, Storage and handling of biomass.
Feedstock for biogas, Microbial and biochemical aspects- operating parameters for biogas production. Kinetics and mechanism- High rate digesters for industrial waste water treatment.
Thermo chemical conversion of lignocelluloses biomass. Incineration, Processing for liquid fuel production. Pyrolysis -Effect of particle size, temperature, and products obtained.
Thermo chemical Principles: Effect of pressure, temperature, steam and oxygen. Fixed and fluidized bed Gasifiers- Partial gasification of biomass by CFB. Combustion of woody biomass-Design of equipment. Cogeneration using bagasse- Case studies: Combustion of rice husk.

Text books & Reference books:

- Chakraverthy A, "Biotechnology and Alternative Technologies for Utilization of Biomass or Agricultural Wastes", Oxford & IBH publishing Co, 1989.
- Amit Sarin, Biodiesel: Production And Properties, RSC.
- CAPAREDA, Introduction To Biomass Energy Conversions, T&F INDIA
- Ozcan Konur, Bioenergy And Biofuels, T&F/CRC PRESS
- D. Yogi Goswami, Frank Kreith, Jan. F .Kreider, "Principles of Solar Engineering", 2nd Edition, Taylor & Francis, 2000, Indian reprint, 2003[chapter 10]
- Mital K.M, "Biogas Systems: Principles and Applications", New Age International publishers (P) Ltd., 1996. 4.Nijaguna, B.T.,Biogas Technology, New Age International publishers (P) Ltd.,2002
- VenkataRamana P and Srinivas S.N, "Biomass Energy Systems", Tata Energy Research Institute, 1996.
- Khandelwal. K. C.and Mahdi S. S, "Bio-Gas Technology", Tata McGraw-Hill Pub. Co.Ltd, 1986.

ESTE2 206 (JAN) *(Elective)*
Hydrogen Energy
L-T-P: 3-1-0

Hydrogen Production – Production of hydrogen from hydrocarbons –Oxidative and non-oxidative processes, coal. H_2 production using nuclear energy and renewables- wind, biomass, solar. Production of hydrogen suing electrochemical and photoelectrochemical water splitting. Hydrogen separation and purification – Pressure swing adsorption; Solvent based absorption, membrane separation, cryogenic separation etc. Hydrogen storage – compressed storage, liquid state storage, solid state storage, different materials for storage – metal hydrides, high surface area materials, complex and chemical hydrides, hydrogen storage system – design and materials aspects. Hydrogen sensing – Traditional methods of hydrogen sensing using thermal conductivity measurements or GC, MS or laser gas analysis; Solid state sensors- their working principle and applications in industrial scale applications. Hydrogen Safety – History of accident;, physiological, physical and chemical hazards; hydrogen properties associated with hazards; Hazard spotting, evaluation and safety guidelines; Hydrogen safety codes and standards. Hydrogen economy.

Text books & Reference books:

- Angelo Basile , Francesco Dalena, Cahterine E. Gregoire Pedro, Francis Lau, Advances In Hydrogen Energy, Springer
- Iet Publishing, Hydrogen Production, Separation And Purification For Energy (Energy Engineering)
- Mehmet Sankir, Nurdan Demirci Sankir, Hydrogen Production Technologies, John Wiley
- Hydrogen And Fuel Cells : Emerging Technologies And Applications , 3rd Edition, Bent Sørensen Giuseppe Spazzafumo

ESTE2 207 (JAN) *(Elective)*
Power Sources for Electric Vehicles
L-T-P: 3-1-0

The Electric Vehicle Debate, Primary Energy Sources and Alternative Fuels for Transportation, History of Electric Vehicles, Electrochemical Power Sources – Secondary Batteries and Fuel Cells.
Sources- Aqueous Electrolyte Batteries –Lead Acid, Nickel – Iron, Nickel – Zinc, Metal – Air Zinc – Halogen. Non Aqueous Electrolyte Batteries- High Temperature Batteries, Organo Electrolyte and Solid State Batteries.
Overview of Performances of Candidate Secondary Battery Systems-Fuel Cells - Acid Systems, Direct Methanol / Air Systems ,Alkaline Systems-Overview of Performances of candidate Fuel Cell Systems, Battery / Fuel cell / Internal.
Combustion Engine Hybrid Electric Vehicles, Laboratory Test of Electric Vehicle Batteries, Vehicle tests with Electric Vehicle Batteries, Safety of electric vehicle, Charging station and Fast Charging of Li-ion battery. Future of Electric Vehicles.

Text books & Reference books:

- Power Sources for Electric Vehicles, Edited by B.D. McNicol and D.A.J. Rand, Elsevier Publications.1998

- Lithium Batteries for Hybrid Cars By John Voelcker, IEEE Spectrum, 1990
- Hand Book of Batteries and Fuel cells, 3rd Edition, Edited by David Linden and Thomas. B. Reddy, McGraw Hill Book Company, N.Y. 2002.
- Fuel Cells, Principles and Applications, Viswanathan, B. and Scibioh, Aulice M, Universities Press, 2006.
- The Essential Hybrid Car Handbook: A Buyer's Guide (Paperback)by Nick Yost, The Lyons Press, N.Y. 2006.
- John G. Hayes, G. Abas Goodarzi, Electric Powertrain: Energy Systems, Power Electronics And Drives For Hybrid, Electric And Fuel Cell Vehicles, John Wiley
- Fuel cell and their applications, K. Kordesch, G. Simader, VCH, Weinheim, Germany, 1996.
- Paul Breeze, Fuel Cells, 1st Edition, Elsevier
- Nigel P.Brandon, Enrique Ruiz-Trejo and Paul Boldrin, Solid Oxide Fuel Cell Lifetime And Reliability : Critical Challenges In Fuel Cells, 1st Edition, Elsevier

ESTE2 208 (JAN) *(Elective)*
Wind Energy Conversion Systems
L-T-P: 3-1-0

Wind machine types, classification, parameters. Wind, its structure, statistics, measurements, data presentation, power in the wind. Wind turbine aerodynamics, momentum theories, basic aerodynamics, airfoils and their characteristics, Horizontal Axis Wind Turbine (HAWT) - Blade Element Theory, wake analysis, Vertical Axis Wind Turbine (VAWT) aerodynamics. HAWT rotor design considerations, number of blades, blade profile, 2/3 blades and teetering, coning, power regulation, yaw system, tower. Wind turbine loads, aerodynamic loads in steady operation, wind turbulence, static - dynamic - fatigue analysis, yawed operation and tower shadow, WECS control system, requirements and strategies. Wind Energy Conversion System (WECS) siting, rotor selection, Annual Energy Output (AEO). Synchronous and asynchronous generators and loads, integration of wind energy converters to electrical networks, inverters. Testing of WECS. Noise. Miscellaneous topics.

Text books & Reference books:

- Freris L.L., Wind Energy Conversion Systems, Prentice Hall 1990.
- Spera D.A., Wind Turbine Technology: Fundamental Concepts of Wind Turbine Engineering, ASME Press, NY 1994.
- Johnson, G.L., Wind Energy Systems, Prentice Hall, 1985.
- Imene Yahyaoui, Advances In Renewable Energies And Power Technologies: Solar And Wind Energies, Volume 1, 1st Edition, Elsevier
- Mohamed A. El-Sharkawi, Wind Energy: An Introduction
- P. Jain, Wind Energy Engineering, Mc Graw Hill India

ESTE2 209 (JAN) *(Elective)*
Nuclear Reactor Theory
L-T-P: 3-1-0

Owing to the extensive use of nonlinear optical phenomena and Ultrafast lasers in various fields, we believe a good understanding of these principles is essential for students in all science and engineering disciplines, students involved in the area of Photonics, RF and Microwave systems, Optical Instrumentation and Lightwave (Fiber-optic) Communications. In addition, this course intends to prepare students to pursue advanced topics in more specialized areas of optics such as Biomedical Imaging, Quantum optics, Intense field phenomena etc.

Text books & Reference books:

- J.R. Lamarsh, Introduction to Nuclear Reactor Theory, Wesley, 1966
- Malcolm Joyce, Nuclear Engineering : A Conceptual Introduction To Nuclear Power, 1st Edition, Elsevier
- James J. Duderstadt, Nuclear Reactor Analysis, Wiley India
- K. Linga Murty, Indrajit Charit, Introduction To Nuclear Materials: Fundamentals And Applications, John Wiley.

ESTE2 210 (JAN) *(Elective)*
L-T-P: 3-1-0
Overview of Material Characterization Techniques

Principles, instrumentation, design and application of UV, visible and IR spectroscopy, mass spectrometry, Mossbauer and NMR spectroscopy, X-ray methods of analysis including powder diffraction, wavelength and energy dispersive x-ray fluorescence. Electron microscopy and microprobe. ESCA and Auger techniques, photo electron spectroscopic methods, scanning tunneling and atomic force microscopy. Chromatography, thermal analysis including DTA, DSC and TGA.Hands on training on preparation of fine particles, growth of single crystals and thin films and their thermal analysis, magnetic measurement, X-ray diffraction, SEM and TEM analyses, electrical and dielectric measurements.

Text books & Reference books:

- George M. Crankovic (Ed.), ASM Handbook: Volume 10: Materials Characterization, ASM International, 1986 Robert Cahn (Ed.), Concise Encyclopaedia of Materials Characterization,2nd Edition, Elsevier, 2004
- Charles Evans, Richard Brundle and Shaun Wilson, Encyclopaedia of Materials Characterization: Surfaces,Interfaces, Thin Films, Elsevier, 1992
- Tantra, Ratna, Nanomaterial Characterization: An Introduction, Wiley (2016)

M.TECH – Energy Science and Technology (EST) SYLLABUS FOR IIIrd SEMESTER

EST 301 (AUG) *(Compulsory Course)*
Summer Research Internship

Summer research internship after IInd Semester for 4 weeks to 6 weeks. Submission of internship report and seminar presentation. Highly recommended for Industrial training.

EST 302 (AUG)
Comprehensive Viva

After completion of all the courses and summer research internship, all the candidates will appear for the comprehensive viva.

EST 303 (AUG)
Research Methodology & Technical Writing
L-T-P: 3-0-0

Research Methodology:
Research process, types of research, problem identification and hypothesis formulation, Research design, methods of data collection, reliability and validity, data presentation, and report preparation.
Introduction to Research Communication:
Grammar and Rhetoric: Sentential and supra sentential structure, Narrative and structuring argument, common error in composition. Reading skills for literature review: Previewing techniques, understanding the gist of an argument, identifying the topic sentence.
Writing skills (Part-I)
Sentence formation, Use of appropriate diction, paragraph and essay writing, coherence and cohesion. Summarizing, paraphrasing, outlining, Non-linear description, Narrative, Instruction and reporting. Descriptive and explanatory, analytical and argumentative writing, enhancing editing skills, punctuation.
Writing skills (Part-II)
Introduction to terminology, concept of research. Preparing research proposal/ Synopsis. Formulating thesis statement. Referencing (all style sheet). Writing Introduction, Footnotes/ Endnotes, Conclusion. Preparing Appendix, Bibliography (all style sheets), and Abstract. Writing acknowledgement. Concept of Keywords, preparing content page/ list of Tables and Figures. Use of classified materials, Plagiarism and copyright materials.

Text book & Reference books:
Ranjit Kumar, *Research methodology: a step-by-step guide for beginners*, SAGE Publications India Pvt Ltd.
C.R. Kothari, *Research Methodology: Methods and Techniques*, New Age International, 2004.
Michael H. Markel, *Handbook of Technical writing*, Bedford/St Martins, 2012
Thomas N. Huckin, *Technical Writing and Professional Communication: For Non-native Speakers of English*, McGraw Hill, 1991.
Michael H. Markel, *Technical Writing Essentials*. St. Martin's Press, 1988.
Sharon J Gerson, Steven M Gerson, *Technical writing: Process and product*, Fifth edition, Pearson Education, 2006.

EST 304 (AUG) 8:0

M. Tech Thesis/Project
L-T-P: 0-0-16

The student will be encouraged to finalize the area of the project work during the end of second semester itself. The project work will start in the third semester. The project work aims to generate new and useful knowledge in the field of energy. The project works related to industry specific problem solving are also encouraged. The project can be carried out in the University or in collaboration with an industry/research organization/other University. If a student undergoes his/her project work outside the University, one External Supervisor form the organization will be there along with one faculty member from the Department as an Internal Supervisor. The students are expected to complete a good quantum of the work in the third semester. In the end of the third semester, student has to present a seminar on the progress of his/her research work. **A brief project report needs to be submitted during the presentation of the work.** There shall be evaluation of the work carried out at the end of the third semester.

M.TECH – Energy Science and Technology (EST) SYLLABUS FOR IVth SEMESTER

EST 401 (Jan) 12:0
Final M. Tech Thesis/Project
L-T-P: 0-0-24

The project work started in the third semester will be extended in the fourth semester. On completion of the project work, the student shall submit a thesis to the department for examination. There shall be evaluations of the project work by a committee constituted by the department with an external examiner. The thesis will be examined by external and/or internal examiners. The candidate has to appear an open *viva-voce* examination on his/her thesis. The students will be encouraged to publish research papers based on his/her findings in Indexed Journals and/or reputed conferences.